Fixed Costs and Steep Improvement Curves

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Fixed Costs Contribute to Steeper Curves

- **Purpose of Study:**
  - **Does the amortization of fixed costs over low quantities contribute to steeper cost curves?**

- **Methodology:**
  - **Derived Fixed/Variable CER from F-18A/B data and compared the CER results for various aircraft quantity profiles**

- **Conclusions:**
  - **Low build-up rates create steeper bottom-line learning curves**
  - **Learning and rate curves may not always mimic fixed and variable curves**

Fixed Cost

- **Fixed Costs Include**
  - **Program Support Tasks, e.g., Program and Business Management**
  - **Lot charges, e.g., Set-up, Lot testing**
  - **Level of effort tasks in Engineering, Manufacturing Engineering, Quality**
  - **Overhead expenses**
  - **Administrative and travel expenses**

F-22 Supplier Curves Reflect Effects of Fixed Cost With Low Quantities

- **Suppliers estimated learning curves from history, then applied fixed costs and spread over quantities**
  - **Proposals demonstrate the resultant learning curves shown**

Supplier A	**75%**
Supplier B	**75%**
Supplier C	**74.5%**
Supplier D	**74.8%**

Low F-22 Quantities Affect Supplier Curves

- **F-22 Supplier Quantities are significantly lower than recent fighter production quantities**

F-22	**2 , 6, 10, 16, 24, 36**
F-16	**27, 110, 169, 200, 198**
F-15	**30, 62, 72, 132, 108**
F-18	**9, 25, 79, 87, 126**

Low F-22 Quantities Affect Supplier Curves

- **White paper by L.J. Pierce of LMTAS indicates that as the percentage of fixed costs increase the resultant learning curves are steeper**

Variable Cost Curve	Total Cost Curve if Fixed Cost is % Total 20%	40%	60%
80%	75%	70%	65%
85%	80%	74%	68%
90%	84%	78%	71%
95%	89%	82%	74%

Test of Low Rate Build-up on Improvement Curves

- **AFCAA analysis based on F-18 Airframe CER supports steeper curves for lower production build-up rates**
  - **Derived F-18 Airframe Fixed/ Variable CER**
  - **Ran F-18 Fixed/Variable CER for different quantity build-up rates**
- **Calculated fixed, variable , and total costs for each build-up.**
  - **Derived bottom line improvement curve slopes for total costs.**

F-18 AIRFRAME FIXED & VARIABLE

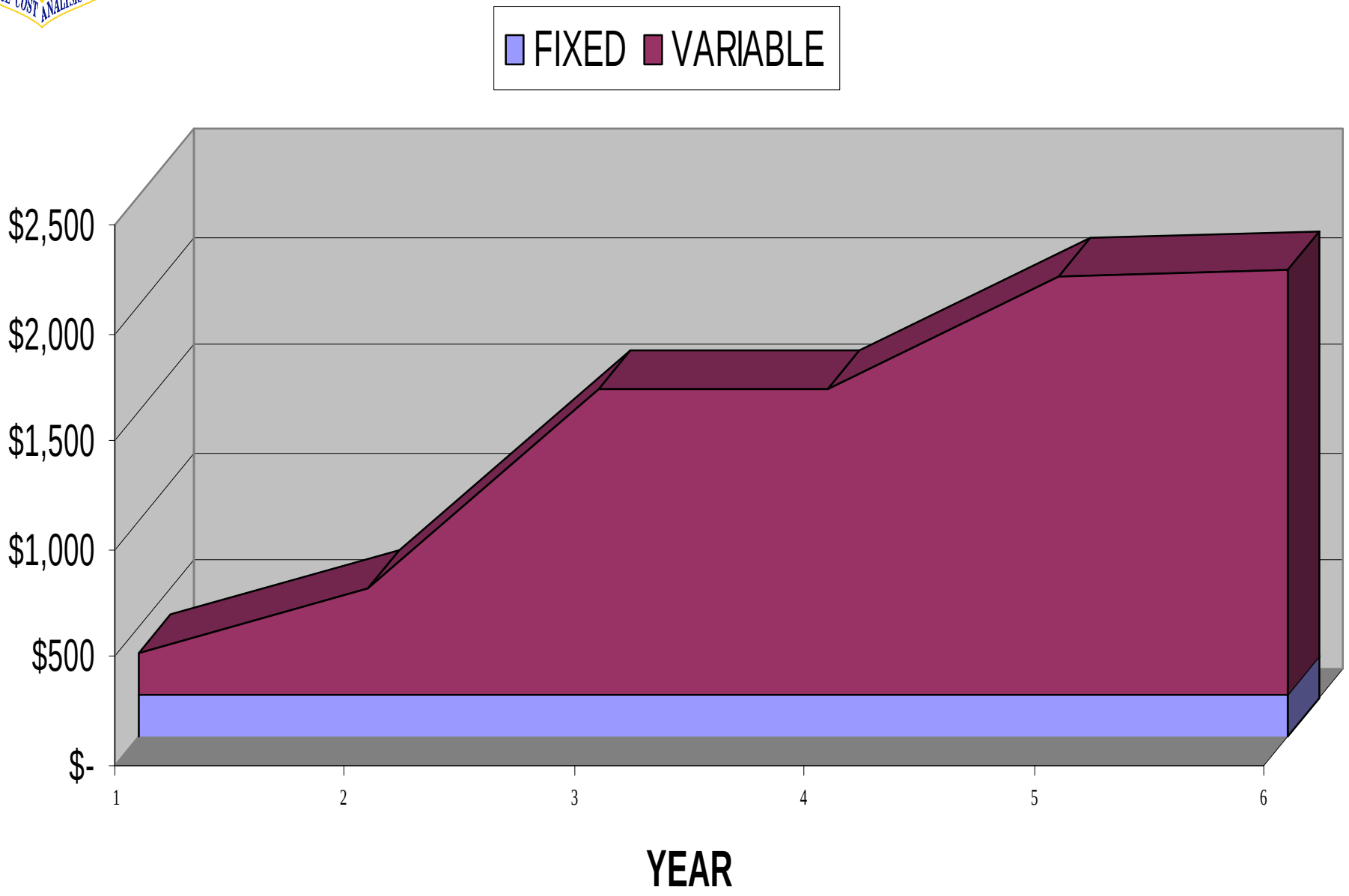
- **Derived Variable/Fixed CER for F-18 Airframe $**

Lot Avg Cost (M) = T1 x (midpt)^{b} + Fixed Cost/Lot Qty

T1 (Variable) =31.3
b (Variable) = -0.127 (Slope = 91.6%)
Fixed Cost = 186.4

- **RB-SQ=99.77 COEF VAR= 2.08%**

F-18 AIRFRAME FIXED & VARIABLE TOTAL COSTS ($M)



Effects of Low Rate Build-up on Improvement Curves

	F-18 A/B QTY	Fixed % of Total Cost
PRTV	9	48%
Lot 1	25	27%
Lot 2	79	12%
Lot 3	87	12%
Lot 4	126	9%
Lot 5	135	9%
	461	

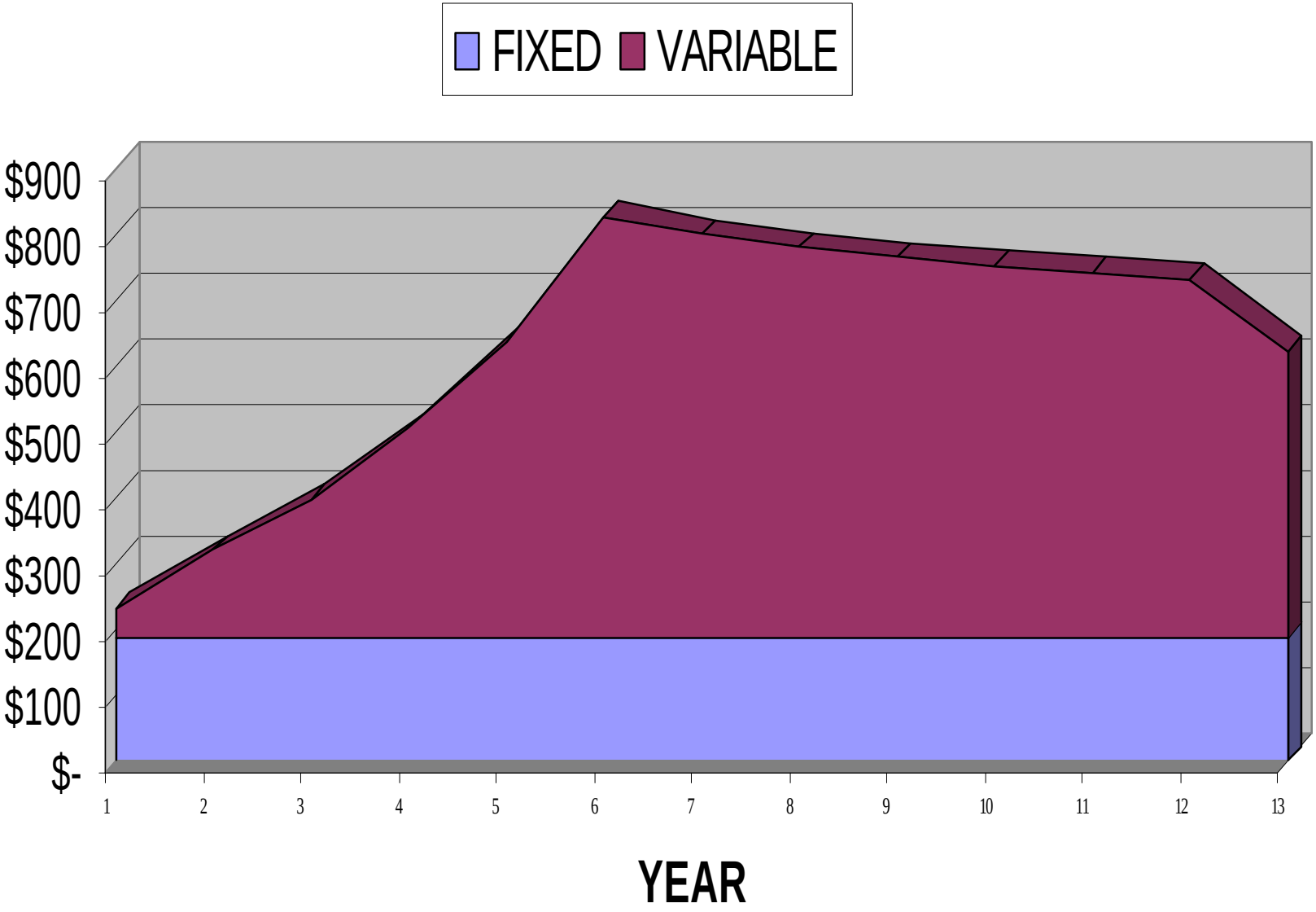
Resultant Total Cost Improvement Curve 82.1%

Effects of Low Rate Build-up on Improvement Curves

	F-18 A/B QTY	Fixed % of Total Cost	F-22 QTY	Fixed % of Total Cost
PRTV	9	48%	2	80%
Lot 1	25	27%	6	58%
Lot 2	79	12%	10	47%
Lot 3	87	12%	16	37%
Lot 4	126	9%	24	29%
Lot 5	135	9%	36	23%
Lot 6			36	23%
Lot 7			36	24%
Lot 8			36	24%
Lot 9			36	25%
Lot 10			36	25%
Lot 11			36	25%
Lot 12			29	30%
	461		339	

Resultant Total Cost Improvement Curves F-18 = 82.1% F-22 = 76.8%

F-22 PROFILE F-18 AIRFRAME FIXED & VARIABLE TOTAL COSTS ($M)



Effects of Low Rate Build-up on Improvement Curves

	F-18 A/B QTY	Fixed % of Total Cost	F-15 A/B QTY	Fixed % of Total Cost
PRTV	9	48%	30	24%
Lot 1	25	27%	62	14%
Lot 2	79	12%	72	13%
Lot 3	87	12%	108	10%
Lot 4	126	9%	24	11%
Lot 5	135	9%	108	10%
	461		404	

Resultant Total Cost Improvement Curves F-18 = 82.1% F-15 = 87.7%

Effects of Low Rate Build-up on Improvement Curves

	F-18 A/B QTY	Fixed % of Total Cost	F-14 QTY	Fixed % of Total Cost
PRTV	9	48%	26	26%
Lot 1	25	27%	48	17%
Lot 2	79	12%	48	18%
Lot 3	87	12%	50	18%
Lot 4	126	9%	80	13%
Lot 5	135	9%	86	13%
Lot 6			45	22%
Lot 7			44	23%
	461		427	

Resultant Total Cost Improvement Curves F-18 = 82.1% F-14 = 90.3%

Effects of Low Rate Build-up on Improvement Curves

	F-18 A/B QTY	Fixed % of Total Cost	F-16 A/B QTY	Fixed % of Total Cost
PRTV	9	48%	27	24%
Lot 1	25	27%	110	9%
Lot 2	79	12%	169	7%
Lot 3	87	12%	200	6%
Lot 4	126	9%	198	6%
Lot 5	135	9%	169	8%
	461		873	

Resultant Total Cost Improvement Curves F-18 = 82.1% F-16 = 88.3%

Effects of Low Rate Build-up on Improvement Curves

	F-18 A/B QTY	Fixed % of Total Cost	F-18 E/F QTY	Fixed % of Total Cost
PRTV	9	48%	12	41%
Lot 1	25	27%	20	31%
Lot 2	79	12%	30	25%
Lot 3	87	12%	36	23%
Lot 4	126	9%	42	21%
Lot 5	135	9%	48	19%
Lot 6			48	20%
Lot 7			48	20%
Lot 8			48	20%
Lot 9			48	21%
Lot 10			48	21%
Lot 11			48	21%
Lot 12			48	21%
Lot 13			24	36%
	461		548	

Resultant Total Cost Improvement Curves F-18A/B = 82.1% F-18E/F = 88.6%

Effects of Low Rate Build-up on Improvement Curves

	F-18 A/B QTY	Fixed % of Total Cost	V-22 QTY	Fixed % of Total Cost
PRTV	9	48%	5	60%
Lot 1	25	27%	7	54%
Lot 2	79	12%	7	55%
Lot 3	87	12%	10	48%
Lot 4	126	9%	20	32%
Lot 5	135	9%	26	28%
Lot 6			39	21%
Lot 7			39	22%
Lot 8			39	23%
Lot 9			39	23%
Lot 10			34	26%
Lot 11			30	29%
Lot 12			30	29%
Lot 13			32	28%
Lot 14			32	28%
Lot 15			30	30%
Lot 16			30	30%
Lot 17			9	59%
	461		458	

Resultant Total Cost Improvement Curves F-18 = 82.1% V-22 = 84.9%

Effects of Low Rate Build-up on Improvement Curves

	F-18 A/B QTY	Fixed % of Total Cost	JSF QTY		Fixed % of Total Cost	
PRTV	9	48%	4		67%	
Lot 1	25	27%	24		27%	
Lot 2	79	12%	42		19%	
Lot 3	87	12%	72		13%	
Lot 4	126	9%	94		11%	
Lot 5	135	9%	120	366	9%	76.3%
Lot 6			156		8%	
Lot 7			194		6%	
Lot 8			194		7%	
Lot 9			194		7%	
Lot 10			194		7%	
Lot 11			194		7%	
Lot 12			194		7%	
Lot 13			194		7%	
Lot 14			170		8%	
Lot 15			146		10%	
Lot 16			146		10%	
Lot 17			146		10%	
Lot 18			143		10%	
Lot 19			110		13%	
Lot 20			110		13%	
Lot 21			11		60%	
	461		2852			

Resultant Total Cost Improvement Curves F-18 = 82.1% JSF = 87.1%

Resultant Total Cost Improvement Curve Slopes

F22	F15	F18	F14
76.8%	87.7%	82.1%	90.3%

F16	F18E/F	V-22	JSF
88.3%	88.6%	84.9%	87.1%

Learning/Rate Curves

- **Typically Cost Analysts have used Learning/Rate Curves to account for fixed costs**

$$\text{Lot Avg Cost (M)} = T1 \times (\text{midpt})^{b} \times (\text{rate})^{r}$$

- **Will the above analysis performed with Learning/Rate curves yield similar results to those obtained using Fixed & Variable curves?**

Fixed/Variable vs. Learning/Rate

- **Derived F-18 Airframe CER based on a learning curve with rate adjustment**

  •Ran Learning/Rate CER for various quantity build-up rates

- **Calculated total costs for each build-up.**

  •Derived bottom line improvement curve slopes for total costs.

- **Resultant bottom line slopes are significantly different in some cases than fixed/variable slopes**

F-18 Airframe Fixed/Variable vs. Learning/Rate

- **Derived Variable/Fixed CER for F-18 Airframe $**

  Unit Cost (M) = 31.3 x (midpt)$^{-0.127}$ + 186.4/Lot Qty

  Variable Learning Slope = 91.6%

  RB-SQ=99.77 COEF VAR= 2.08%

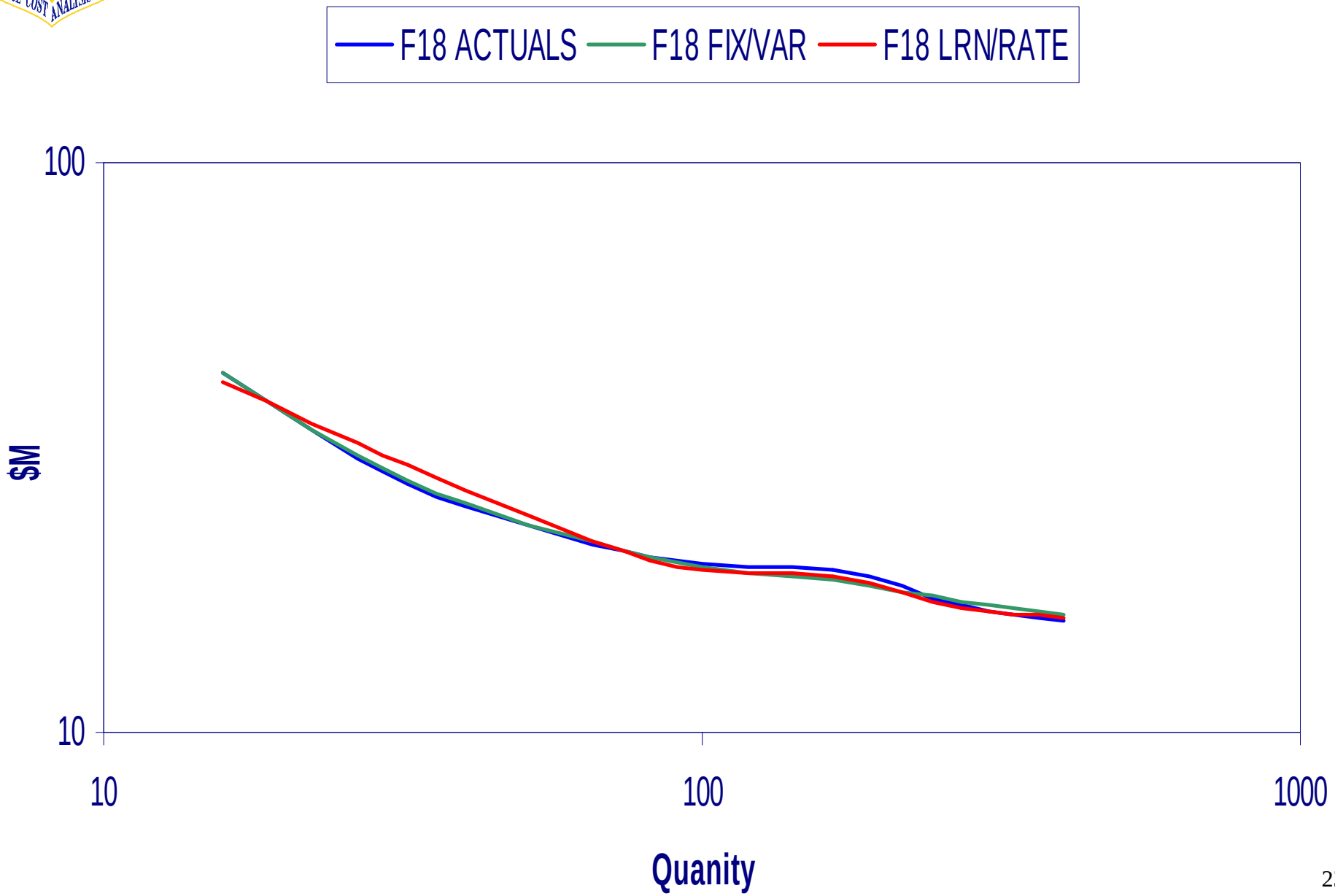
- **Derived Learning/Rate CER for F-18 Airframe$**

  Unit Cost (M) = 88.8 x (midpt)$^{-0.051}$ (rate)$^{-0.288}$

  Learning Slope = 96.5% Rate Slope = 81.9%

  RB-SQ=98.03 COEF VAR= 7.01%

F-18 Airframe Fixed/Variable vs. Learning/Rate



Resultant Slopes
Fixed/Variable vs. Learning/Rate

	F22	F15	F18	F14
FIXED/VAR	76.8%	87.7%	82.1%	90.3%
LRN/RATE	84.4%	87.0%	82.0%	92.1%

	F16	F18E/F	V-22	JSF
FIXED/VAR	88.3%	88.6%	84.9%	87.1%
LRN/RATE	87.2%	91.1%	89.3%	89.1%

Conclusions

- **Resultant learning curves reflect a steeper curve for the F-22 build-up than for other historical programs with larger quantities in the early lots and faster build-up rates**

- **It is improper to use learning only to estimate curves which include fixed costs**

- **Beware -- the application of learning/rate curves to procurement profiles drastically different from history may not always mimic learning curves with fixed costs**